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OF INSECT INFESTATIONS AND  
DENSITY/DISTRIBUTION OF HOST PLANTS Final  
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A Study of the Early Detection of Insect Infestations  
and Density/Distribution of Host Plants

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INTRODUCTION

Studies have demonstrated that photography from aircraft can be used as an effective tool in research and practical applications of agriculture. Hart and Myers (1968) using aerial color infrared film were able to detect light to heavy infestations of brown soft scale, Coccus hesperidum L. on citrus. This work was accomplished with color infrared film at a photographic scale of 1:10,000. Hart et al. (1973) demonstrated that the same technique could be used to detect citrus blackfly, Aleurocanthus woglumi Ashby, infestations in citrus groves. An aerial photographic survey method was developed from these studies that provided a rapid and effective method of detecting these problem areas, thus significantly reducing survey time and expense for this serious citrus pest.

Hart et al., in 1971, were able to identify citrus mealybug infestations using aerial color infrared film. The identification of brown soft scale, citrus mealybug and citrus blackfly infestations on citrus foliage is accomplished by detecting the sooty-mold fungus, Capnodium citri Berk,

which grows on honeydew, an end product of metabolism of these insects. The patterns in which the sooty-mold develops on the foliage provides an effective means for specifically identifying infestations of each of these three pests of citrus. It forms a continuous black pattern on individual crowns as a result of brown soft scale, a mottled appearance on individual crowns as a result of citrus mealybug and a dark spot within a grove as a result of heavy infestations on a limited number (6-12) of trees as a result of citrus blackfly.

Aerial photography, using color infrared film provided detection of three insects, one mite and three diseases on pecans and peaches in South Georgia (J. A. Payne, et al. 1971).

Ants can also be easily detected with photography from aircraft as a result of their characteristic mounds. In 1971 studies by Hart demonstrated that mounds of imported fire ant Solenopsis invicta (Buren) could be detected with aerial infrared color photography and that an inexpensive technique for aerial surveys could be established. Later studies by Green et al. (1975) provided in depth information on precise altitude and effectiveness of this survey technique for imported fire ants. Other ant mounds that can be detected are those produced by the harvester ant, Pogonomyrmex barbatus (F. Smith) and Texas leaf cutting ant, Atta texana (Buckley).

These studies demonstrated that insect infestations of crop plants and pastures that are detectable by aerial photography can be divided into four categories according to the type of damage they cause: (1) honeydew producers from which sooty-mold deposits develop on foliage, (2) those that distort geometric patterns of plants, (3) those that cause color or textural changes in the appearance of foliage and (4) those that produce identifiable structures (i.e. ant mounds).

The ability to rapidly identify the density and distribution of host plants of various pests can provide a major input into large scale eradication programs of established pests, containment or control programs of newly introduced pests, and in studies of population dynamics. Usually the most damaging situation that can occur with an insect pest is the introduction of a destructive species to a new area. This results because the pest insect usually arrives without any of its natural enemies which causes the pest population to increase very rapidly, inflict severe damage to an area, and remain destructive for prolonged periods. A thorough knowledge of all vegetation in areas that are potential hosts of new introductions of insect pests is vital for the prevention, eradication, containment, or control of these pests. Adequate ground surveys of many of these areas are frequently impractical because they are extremely time consuming, costly, and in most cases not very efficient, since many of the areas of concern are inaccessible. In view of this, Hart and associates in 1973 developed techniques for determining the density and distribution of host plants of various pests using photography from aircraft.

Since the photography from aircraft using color infrared film proved successful in the above studies, this study using Skylab data was undertaken to determine the feasibility of using satellite imagery to detect insect infestations and avenues of entry of pests into previously uninfested areas.

#### Methods and Materials:

A task site was established in the Lower Rio Grande Valley from which data was gathered using ground surveys, aerial photographs and Skylab data. Within the task site, two 259 square kilometer (100 square-mile) areas were selected in which data gathering was concentrated. Area 1, which contained a high density of citrus was located northwest of Mission, Texas. Area 2, located 32 kilometers (20 miles) north of Weslaco, Texas contained several varieties of citrus, winter vegetables, sugarcane, irrigated pastures, fallow land and brush-covered land. In addition to these two large plots, three 2.6 square kilometer (one square-mile) plots were selected at random from within the task site in which highly concentrated data gathering was undertaken.

The data gathered by ground survey was concerned with insect infestations, planting densities, variety differences, soil patterns, crop inventories, acreage measurements and location of canals, roadways, drain ditches, lakes and low areas.

Aerial photographic data was acquired with an aerial camera which had a 304.8 mm (12 inch) focal length lens and a 228.6 x 228.6 mm (9 x 9 inch) format. Film used in the camera was color infrared film (2443) with a filter pack containing a Wratten 15 and 40 cc blue filter. Aerial photographs were taken at altitudes of 609, 1524 and 3048 meters (2000, 5000 and 10,000 ft), above ground level providing a scale of 1:2000, 1:5000 and 1:10,000, respectively. A single engine aircraft containing a 450 mm (18 inch) diameter camera port on the floor to facilitate vertical photography was used for a photographic platform. The film was processed at the Citrus Insects Laboratory, Weslaco, Texas. Photography obtained was viewed on light tables with or without magnification and compared with ground truth and Skylab data.

A multispectral camera with aerial black and white infrared film (2424) was also used for gathering aerial data. This camera contains four 150 mm (6 inch) focal length lenses. Each frame recorded four images of the same area simultaneously, each with a format of 57 mm x 103 mm (2.24 x 4 inch). One image was photographed in the green wavelength band, one in the blue band, one in the red band, and one in the near infrared to 900 nanometers. This data was viewed with a multispectral viewer which can be used to combine all four channels, producing a color composite, or to view any of the wavelength bands separately or in combination.

Skylab data was received from S-190A and S-190B cameras. The S-190A camera, a multispectral photographic camera system consists of an array of six 70 mm (2.75 inch) cameras, each equipped with f/2.8 lenses having a focal length of 152.4 mm (6 inch) which provided approximately 25,600 sq. kilometers (9885 sq. miles) of ground cover per frame. Each camera was designated as a station and was equipped with different film and filter combinations. Camera stations one and two contained black and white infrared film (2424) and a CC<sup>1/</sup> filter (0.7-0.8 micrometer) and a DD<sup>1/</sup> filter (0.8-0.9 micrometer), respectively. Station three contained EE<sup>1/</sup> filter (0.5-0.88) and color infrared film (2443). Station four was equipped with a FF<sup>1/</sup> filter (0.4-0.7 micrometer) and hi-resolution color film (SO-356). Stations five and six were equipped with black and white film (SO-022) and contained a BB<sup>1/</sup> filter (0.6-0.7 micrometer) and an AA<sup>1/</sup> (0.5-0.6 micrometer), respectively.

The Earth Terrain Camera, S-190B, utilized 127 mm (5 inch) film and was equipped with an f/4 lens with a focal length of 457.2 mm (18 inch) providing ground coverage of approximately 11,881 sq. kilometers (4587 sq. miles). Earth Terrain Camera imagery was exposed Aug. 29, 1973, Dec. 5, 1973 and Jan. 28, 1974 and was received April 1974. This imagery consisted of high definition black and white aerial film (3414), conventional color film (SO-242) and hi-resolution color infrared film (SO-131).

S-190A data was received during the month of August, 1973. This film was exposed May 30, 1973 and covered a major portion of the task site. A large area south of the task site, in Mexico, was also included in the coverage. The S-190A data was evaluated by comparing it visually with aerial photography and ground data. The black and white multispectral Skylab photography was observed in the multispectral viewer, producing a color composite which was compared with the other data.

When the Skylab 190B film was received, enlarged 35 mm (1.38 inch) transparencies were made from the original scale of 1:1,000,000 to a scale of 1:63,000. This was then projected on a viewing screen to provide a scale of 1:10,000. Using this scale, two agricultural photo-interpreters analyzed all items in each test site on each film type. After analyzing each film independently a comparison study was made of the color IR and conventional color films by projecting them simultaneously. Using this technique color variations in the optical density of the transparencies and geometric patterning provided information necessary for correct identification of the composition of the agricultural scene. The interpretation was aided by the fact that the conventional color film was exposed before a freeze and the color infrared was exposed after the freeze. This freeze caused changes in reflectance characteristics due to destruction and damage of susceptible plant types.



In order to determine the accuracy of the interpretation of various features within the areas, a study was conducted using S-190B color infrared and conventional color film. Within the 259 square kilometer (100 square mile) test area, three 2.6 square kilometer (one square mile) test sites were randomly selected. Ground surveys were conducted to obtain ground truth which was used as a basis for determining accuracy. Aerial surveys using color infrared photography of the three sites were also conducted. All of this data was obtained plus or minus 24 hours of the Skylab pass over the task site.

The Skylab 190B was analyzed to identify various crops in the test site with both color infrared and conventional color film and to evaluate the influence of freezing temperatures and other environmental factors on sugarcane, cabbage, alfalfa and soil reflectance patterns. Since it was anticipated that the planting density of citrus trees would effect the gross reflectance from the crop and thus influence the accuracy of detection of problems, a study was also made on the effect of tree spacing on reflectance.

In order to demonstrate the ability to quantify differences between brushland, sugarcane and citrus, a density study of the various areas was conducted on conventional color S-190B film. Using a 1:63,000 scale transparency, six randomly selected density readings on each film type were made with a transmission densitometer that has a 1-mm aperture.

Since color infrared photographic data was obtained using different types of color infrared film and exposed from different altitudes above the subject being photographed, a comparison test of resolution was undertaken to determine the effects of the different types of film and altitudes on resolution. The 259.2 hectare (640 acre) test plot used for this comparison was located in Area No. 2 (Fig. 1). The plot was composed of crops, fallow land, roads and canals from which precise ground measurements were taken. Objects measured on the ground were located on the aircraft and Skylab data and comparative measurements were taken from each photograph. Only areas of high contrast were used so that the maximum resolution could be obtained.

Photography from aircraft with color infrared film (2443) exposed at a scale of 1:10,000 over the test plot was adjusted to a scale of 1:20,000 to compensate for the smaller adjusted scale of Skylab data and thus make the comparisons of aircraft and satellite data more equitable. Skylab photography, S-190A and S-190B was enlarged photographically to its maximum useable scale which was 1:200,000 for S-190A and 1:30,000 for S-190B. S-190A used EK-2443 color infrared film and S-190B used S0-131, a high resolution color infrared film.

### Results:

The S-190A data provided significant information on areas of vegetation on both sides of the Rio Grande River. On the conventional color film the physical features of the area such as drainage patterns, water courses and some soil characteristics are readily apparent (Fig. 2a). With the color infrared film (Fig. 2b) the patterns of vegetation which appear as shades of red are very clear. Despite reduced resolution much more information about the distribution of vegetation on both sides of the border is evident with the color infrared film. This photography clearly defines the possible avenues of entry of pest insects from Mexico into the United States and the United States into Mexico because of potential host distribution. The multispectral color infrared composite picture (Fig. 2c) which included the spectral region between 0.5 to 0.9 micrometers, intensified the signature of vegetated areas making it possible to see more vegetation and more accurately pinpoint possible avenues of entry of pest insects. Areas of little vegetation and subsequently less stress, are also clearly evident.

Following the freeze of December 21, 1973 sugarcane demonstrated on S-190B data a major change in reflectance but pastures, and annual crops showed little change. This was due to the absence of chlorophyll in the sugarcane brought about by freeze injury. In Fig. 3, the two film types (color IR and conventional color) each exhibited advantages for some problems, but when the films were viewed simultaneously, comparing each item, the accuracy of identification increased markedly. This is due

in varying degrees to the two film types, to the differences in reflectance characteristics that occurred after a freeze, and to the combination of both.

With the color infrared film, annual crops, fallow land, variations in soil color and low areas were correctly identified 100% of the time. Citrus was identified with 93% accuracy. With conventional color film the accuracy of identifications of citrus dropped to 80% but when both films were compared, citrus was identified correctly in every instance.

When comparing the 2 film types the only items identified with less than 100% accuracy, as indicated in Fig. 3, were brush, homesites, variations in planting density of citrus, and canals.

The best resolution obtained from S-190B data was 8.2 meters (27 feet) at areas of high contrast with conventional color film (S0-242). Resolution of color infrared film (S0-131) was 15.2 meters (50 feet) at areas of high contrast. In Test Area 1, which contained one hundred square miles, it was determined from ground surveys that citrus planting densities varied from 225 trees per hectare to 313 trees per hectare in several groves. This planting density was also very apparent with aerial photography using color infrared film (2443) at a scale of 1:10,000. When viewing S-190B color infrared film, the higher density planting areas appeared darker in color than the lower density plantings (Fig. 4). This was most obvious when citrus was planted on highly reflective soils.

At the time of year S-190B film was exposed, a large portion of the cultivated land in the task site was fallow land. Vegetation present at that time of the year was limited to citrus, sugarcane, winter vegetables, irrigated pastures and cover crops. Uncultivated land contained sparse vegetation of native grasses, shrubs and trees.

With S-190B color infrared film (Fig. 5a) citrus appeared as a very deep red color, separating it from brush and sugarcane which contained little or no visible red color at this time of year. On Dec. 21, 1973 the sugarcane had been subjected to freezing temperatures shortly before it was photographed leaving it devoid of any infrared reflecting chlorophyll. Brush at this time of year does not normally show up well on color infrared film due to the reduced chlorophyll content. With conventional color S-190B data (Fig. 5b) sugarcane which had not been damaged by adverse temperatures when this film was exposed could easily be separated from brush and citrus, but citrus in some instances appeared very similar to brush. In some cases the geometric shape of the field could be used as a determining factor in separating the two. Brush covered areas in the test site are usually large and have irregular patterns whereas most citrus groves in the valley are smaller and more uniform in color and texture throughout.

A field of sugarcane planted on the east side of a large body of water, Delta Lake, demonstrated the moderating effect of large bodies of water on temperature extremes. The sugarcane next to the lake, which

was uninjured by freezing temperatures, appeared red on S-190B color infrared film while cane at a greater distance from the lake appeared black, demonstrating the effect of freeze injury (Fig. 6a). This was the only field that was observed to be undamaged on S-190B color infrared film following the December 21, 1974 freeze.

The most abundant winter vegetable growing at the time S-190B color infrared and conventional color film was exposed was cabbage. With CIR film cabbage appeared bright red which was easily distinguished from the dark red signature of citrus (Fig. 6b). Harvested cabbage fields appeared pink. On the S-190B conventional color transparencies mature cabbage appeared green and after harvest was light green.

Alfalfa appeared as a much brighter red color than all other vegetation growing at the time S-190B color infrared film was exposed. Alfalfa foliage usually provides complete coverage of the soil thus preventing any interference with overall IR reflectance characteristics. An alfalfa field within the first area of the task site had suffered considerable wind damage leaving areas within the field void of vegetation. This was very apparent when viewing S-190B color infrared film (Fig. 6c) because of the bright red reflectance of the undamaged alfalfa compared to the white reflectance of dry soil where the damage occurred.

Problems in sugarcane fields such as chlorotic areas are hard to detect from the ground due to dense planting. With aerial photography, these areas can be easily seen. Chlorotic areas were detected in a

sugarcane field when viewing S-190B conventional color film. The smallest area that could be seen was 9 meters (30 feet) in diameter when magnified to a scale of 1:125,000. Figure 6d is an example of a sugarcane field containing several chlorotic spots. Approximately 4 hectares (10 acres) of the 16.2 hectares (40 acre) field had chlorotic damage.

Soil reflectance patterns were demonstrated to have an adverse effect on the identification of some citrus problems with data acquired from aircraft and Skylab. In the task site there were two basic patterns of soil reflectance that were consistently evident. These soils appeared either white or of varying intensities of blue. White soils are due to the soil being dry or very sandy. Dark soils in the test site were due to the high moisture content of the soils or deposits of silt that accumulate in various locations. S-190B color infrared data (Fig. 6f) demonstrates fallow land containing light soil with a dark soil pattern running through it. In a citrus grove, where the reflectance of soil blends with the reflectance of foliage, soil patterns can cause difficulty in interpretation of the data from Skylab (Fig. 6e). Dark soil patterns in a citrus grove may appear similar to insect infestations or high density of plantings which cause the foliage to appear darker.

The average diffuse transmission density (6 readings each) for brushland, sugarcane and citrus was 13.1%, 21.0% and 9.8%, respectively (Fig. 7). While there was some overlap in the readings for brushland and citrus, it is evident that the averages are significantly different and that brushland and citrus can be separated with this technique.

Using the ground data and the photographic data, resolutions were established. Aerial color infrared film containing a scale of 1:10,000 provided a resolution of 46 cm (18 inches), S-190A 45.7 meters (150 ft) and S-190B 15.2 meters (50 ft) (Fig. 8).

#### Discussion:

Significant advantages can be gained by the use of satellite data gathering systems to record agricultural information. The principle advantage that it offers over photography from aircraft is that massive areas can be photographed very rapidly which provides precise information under uniform conditions. This in turn limits variability that is introduced by data recording systems that must piece together information gathered from large areas under varying conditions of light and time. When dynamic biological factors are being observed, the greater the light and time variations become the greater the possibility that other variations will be introduced.

Gathering entomological data such as infestation in crops and the density and distribution of host plants of major pests requires precise timing of the data gathering process and detailed information if early detection of pest problems is to be accomplished. This study has demonstrated that three principle factors limit the usefulness of satellite data in acquiring data concerned with crop problems. The first of these factors is the need for the data to be acquired at precisely the time



the scientist determines it is necessary. This requirement will exist whether it is a research study or an applied program. The second factor is the need for greater resolution than was offered by the Skylab photography. The S-190B data provided an indication of what can be done with greater resolution, but unfortunately a limited amount was received and thus was acquired at a time of year when the yield of information available for our study was at a minimum. The third factor required to maximize the usefulness of satellite data for crop problems is a more rapid turn around time. Since these are biological problems, they are subject to change very rapidly. This required that the data be placed in the hands of the scientist at the earliest possible moment after it is acquired.

If practical use of satellite data for solving crop problems is to be accomplished answers to the above mentioned data acquisition and logistic problems must be found.

The optimum season for gathering information on insect pests of citrus is from June through September in most of the citrus areas of the United States. Specific problems may arise at other times however. Photography taken from aircraft during this study effectively verified that pest problems on citrus could be monitored with color infrared photography. The resolution obtained with the S-190B data showed that the insect problems could have been detected from satellite data if the photography had been acquired during the periods of infestation.

### Conclusions:

Satellite data such as that obtained from Skylab S-190B offers promise for detection of some insect pests and the distribution of host plants of various insects pests. The practical applications of this technique will be dependent on accurate timing of data acquisition, maximum resolution and rapid turn around time in receipt of the data.

With comparative observations of film types and seasonal influences on reflectance characteristics, many crop varieties can be identified with Skylab S-190B data. This study showed that citrus, sugarcane, brush, some winter vegetables and grain crops could be identified.

Vegetative patterns in border areas can be detected with Skylab S-190A and S-190B data. This information can be useful in detecting avenues of entry of pest species and areas of stress that require greater vigilance in stopping the spread of destructive species (Fig. 2b).

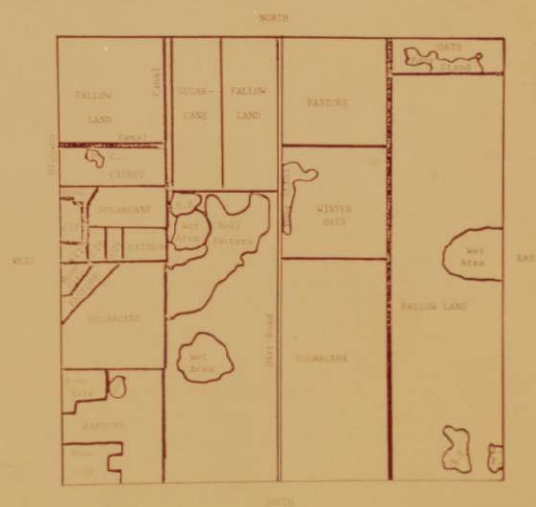
The influence of some environmental factors on crops that may be confused with pest injury, or related factors, can be detected and identified with Skylab S-190B data.

17a

### FIGURE 1



**S-190B COLOR**

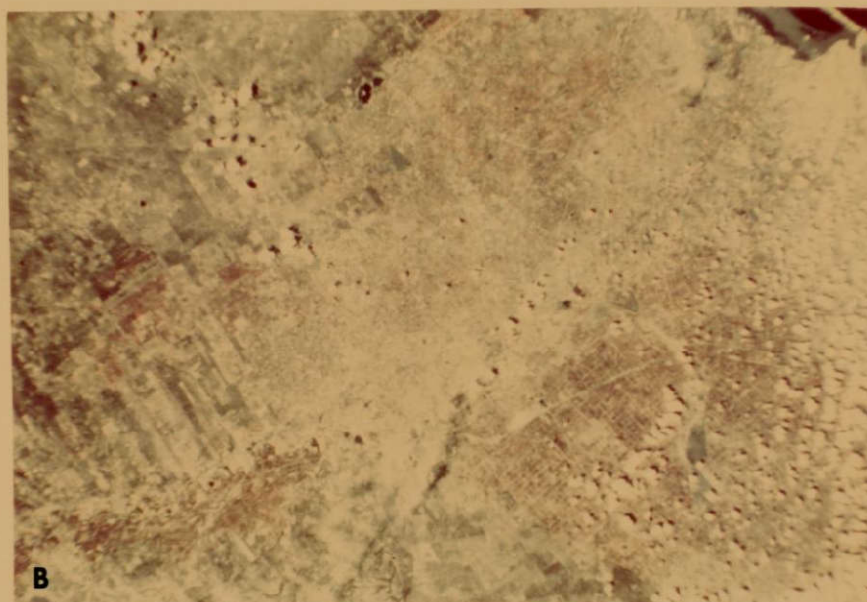
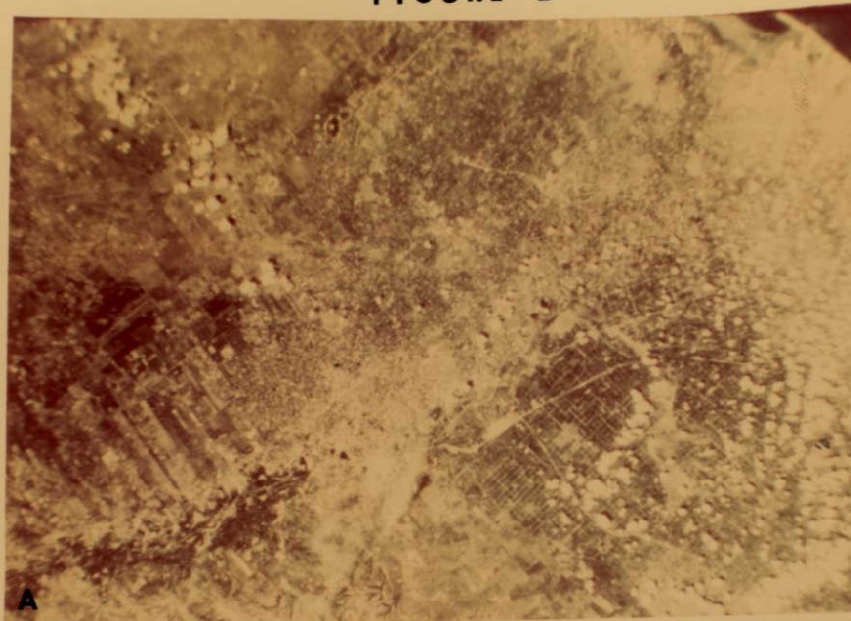


# GROUND DATA



FIGURE 2

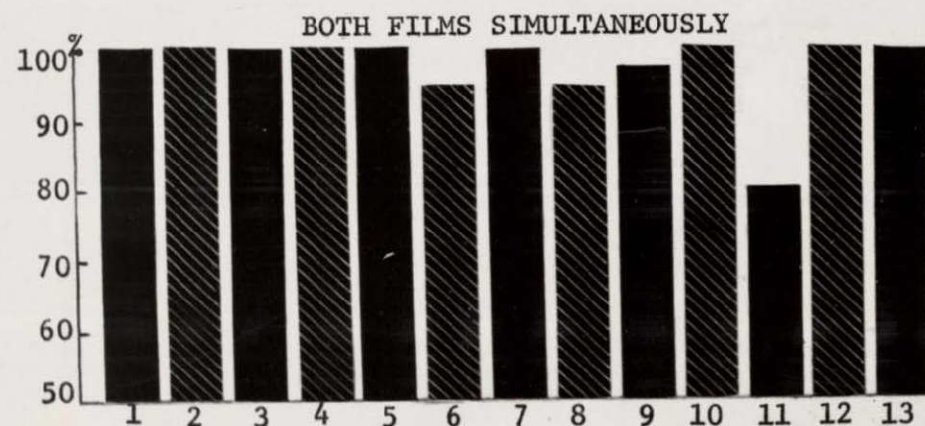
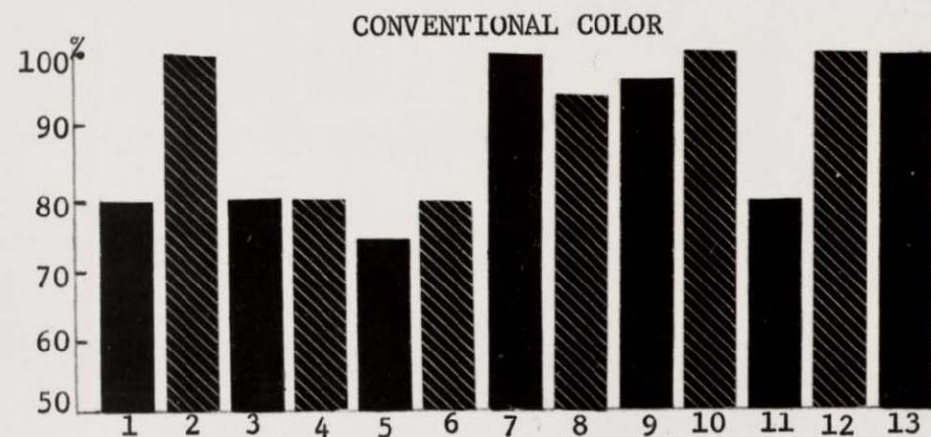
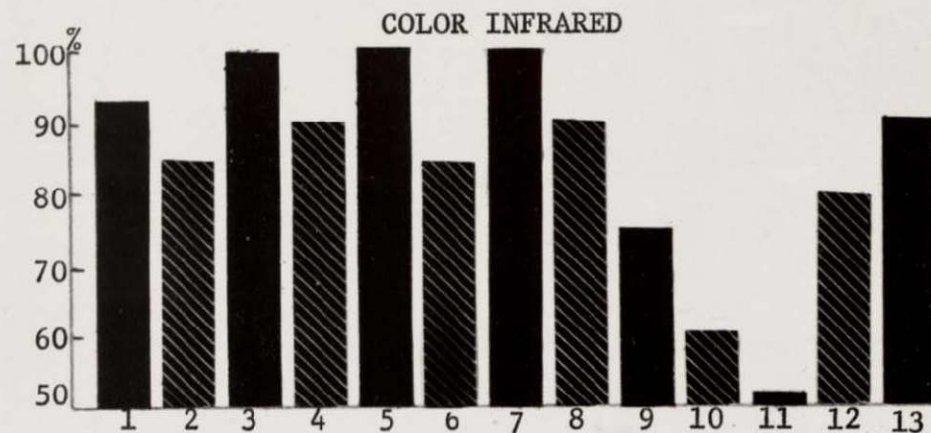
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FIGURE 3

INTERPRETATION ACCURACY FOR SKYLAB 190B DATA



1. CITRUS (2 YRS. AND OLDER)
2. SUGARCANE
3. ANNUAL CROPS
4. PASTURES
5. FALLOW LAND
6. BRUSH
7. SOIL PATTERNS AND LOW AREAS
8. HOMESITES
9. MISSING PLANTS WITHIN CROPS
10. DRAINAGE DITCHES
11. CANALS
12. UNIMPROVED ROADS
13. HIGHWAYS



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FIGURE 4

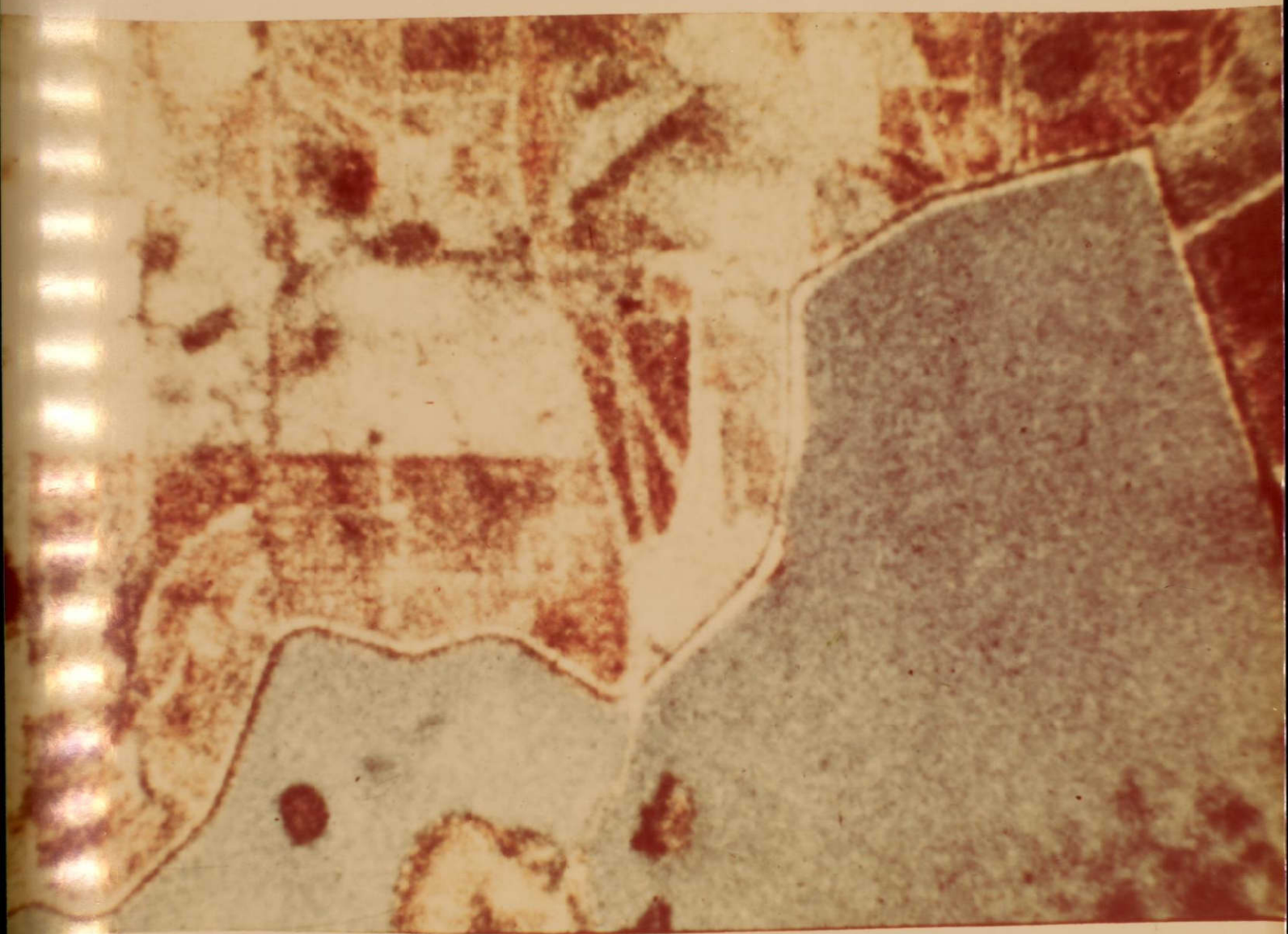
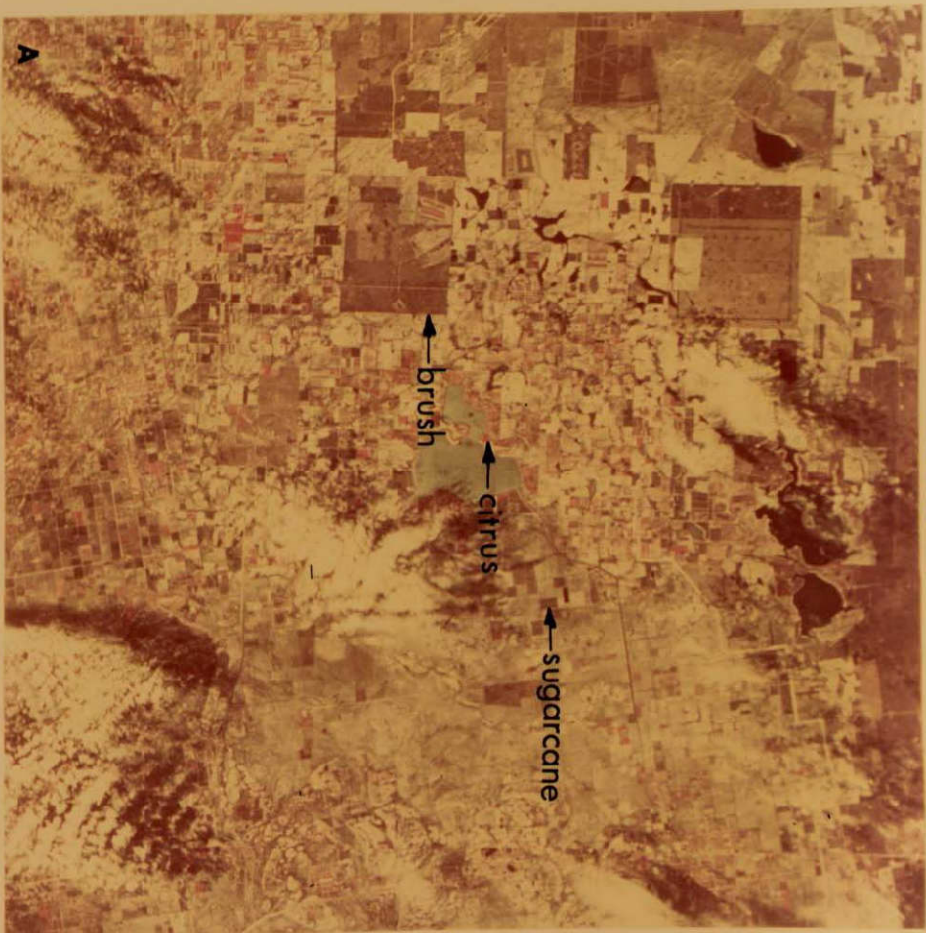




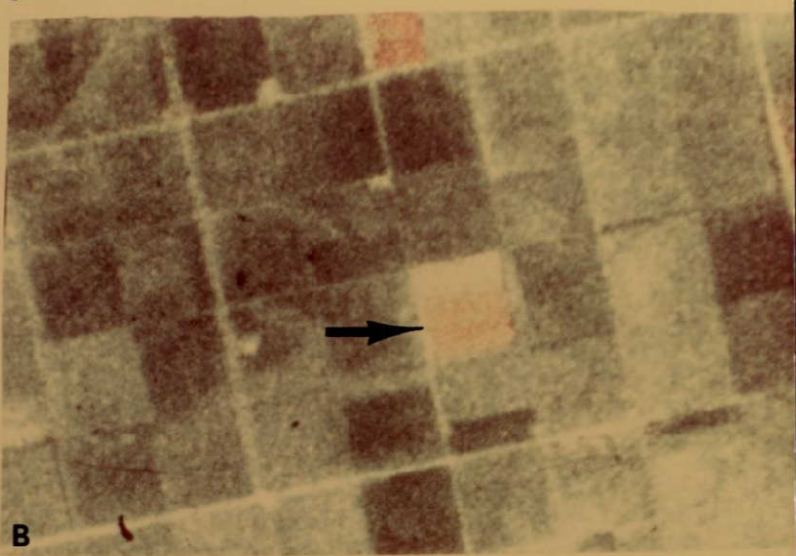
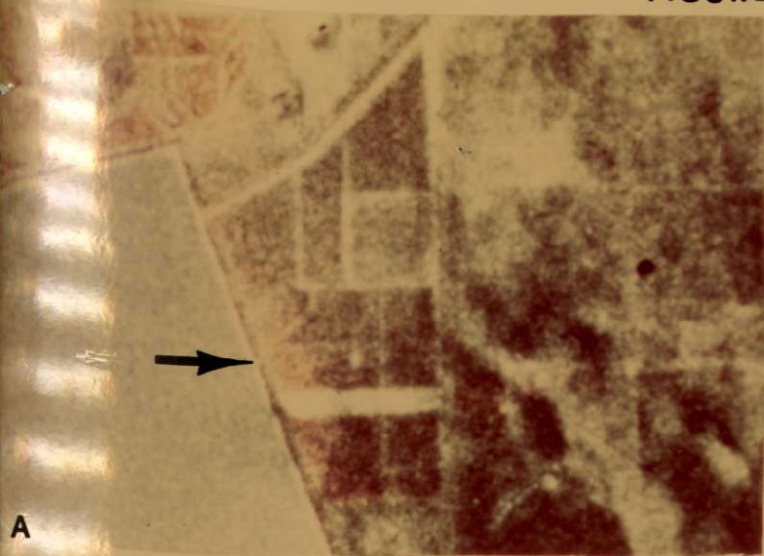
FIGURE 5



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FIGURE 6



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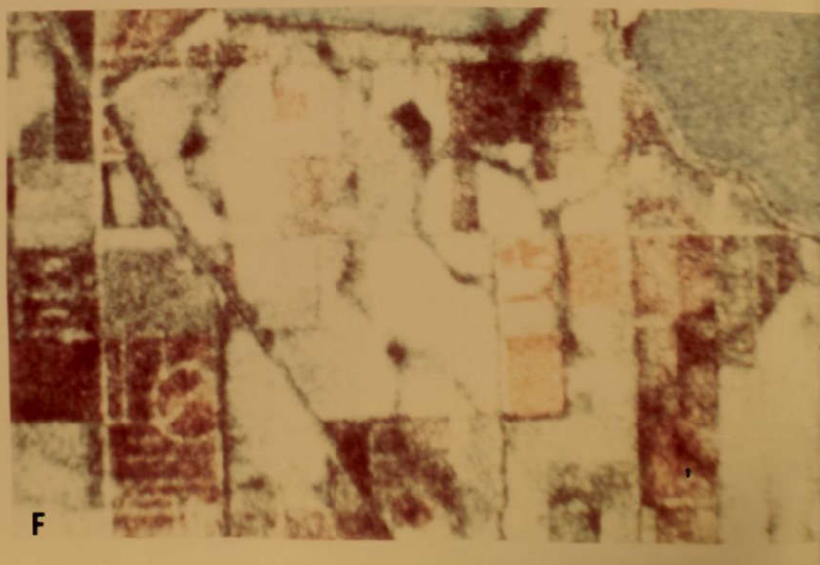
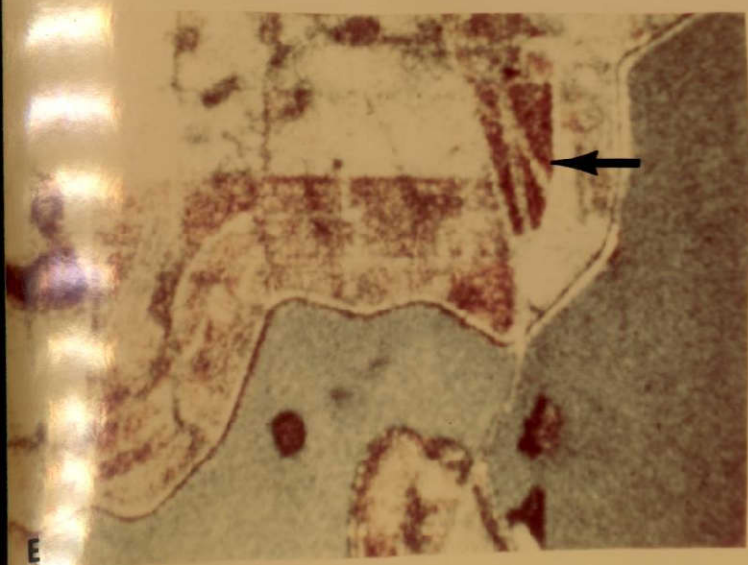
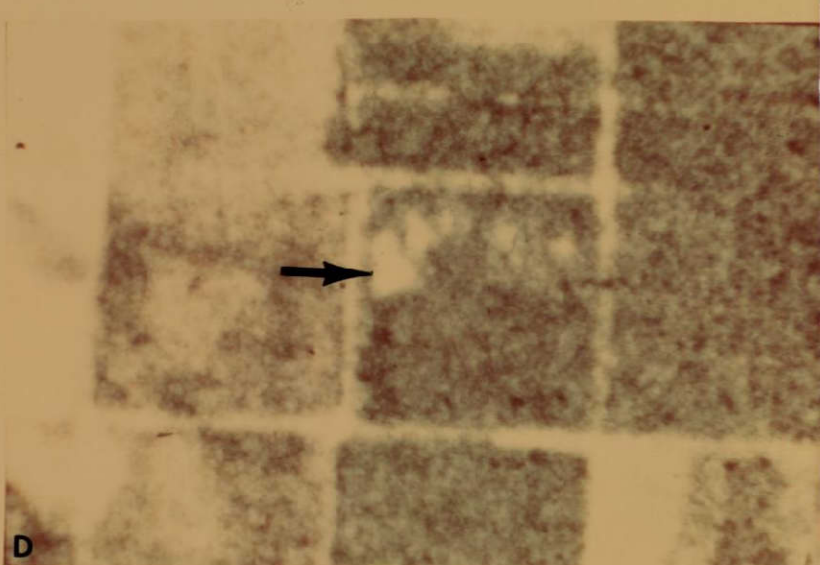
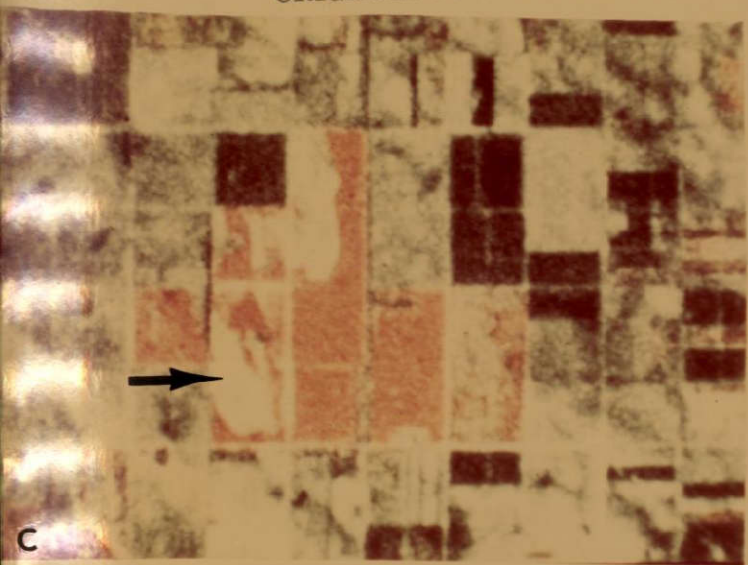
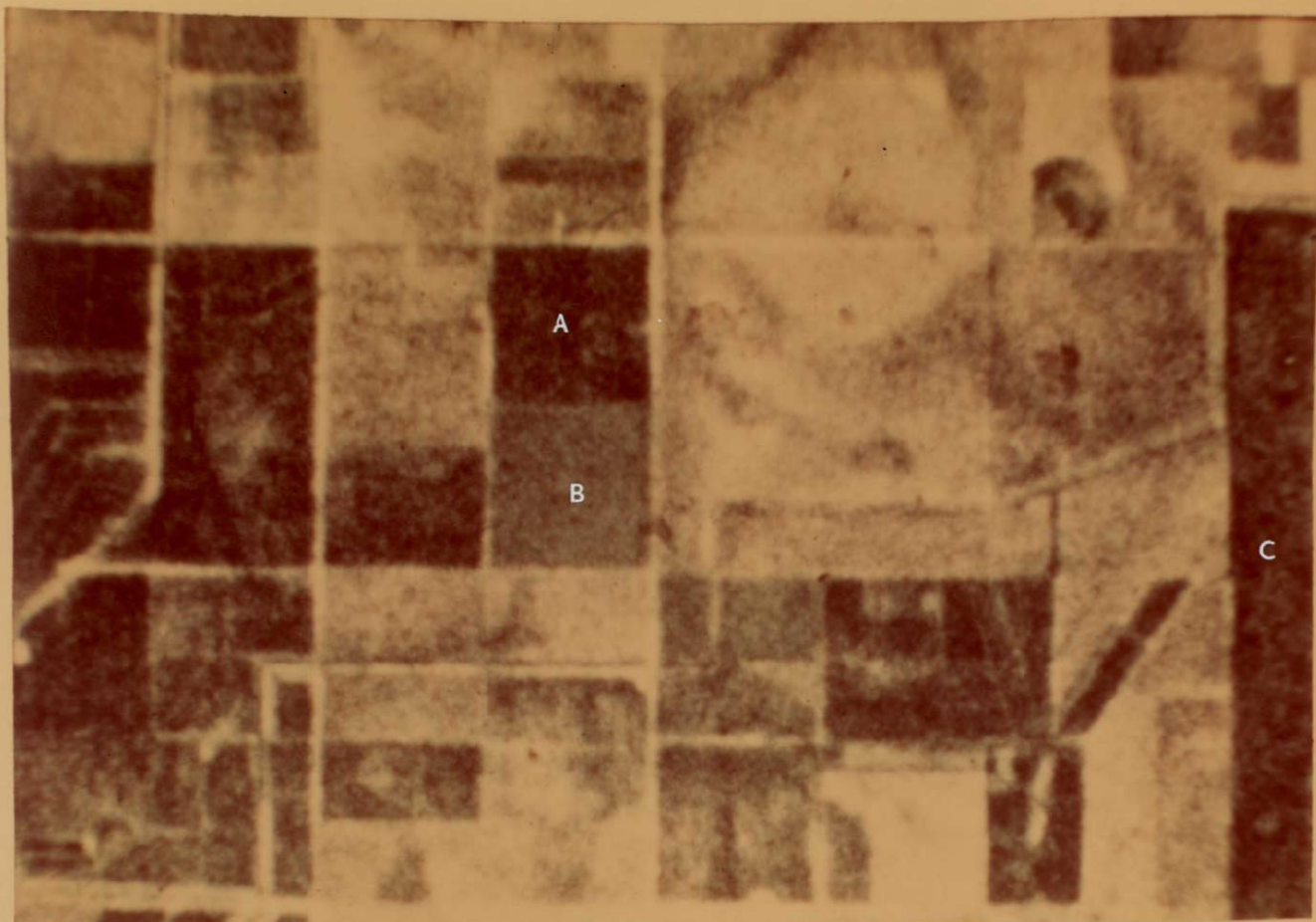


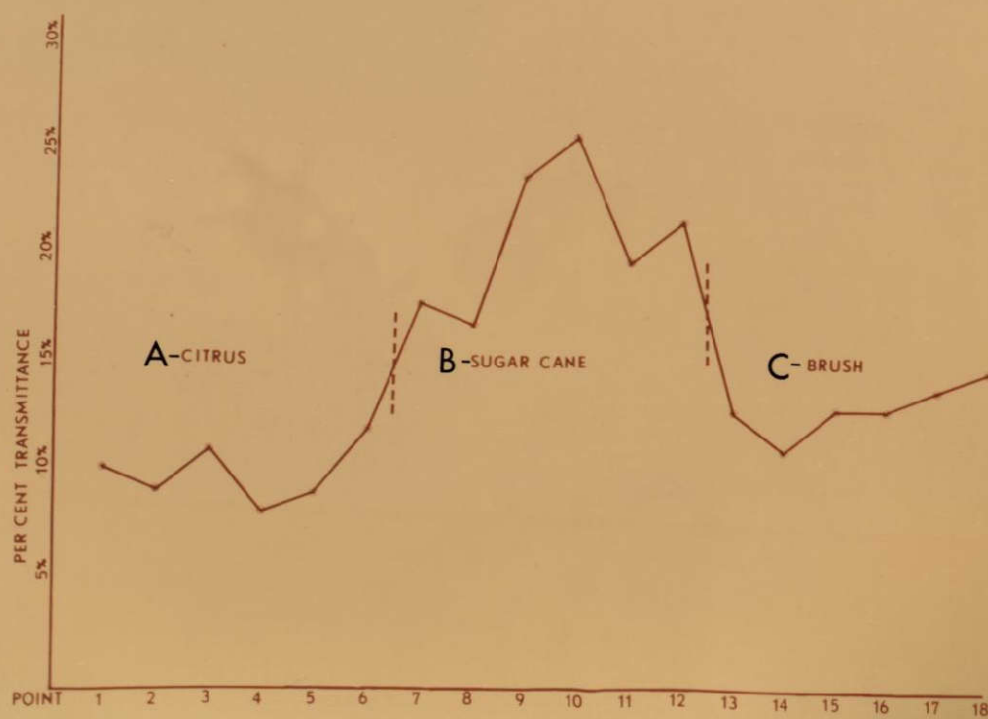


FIGURE 7

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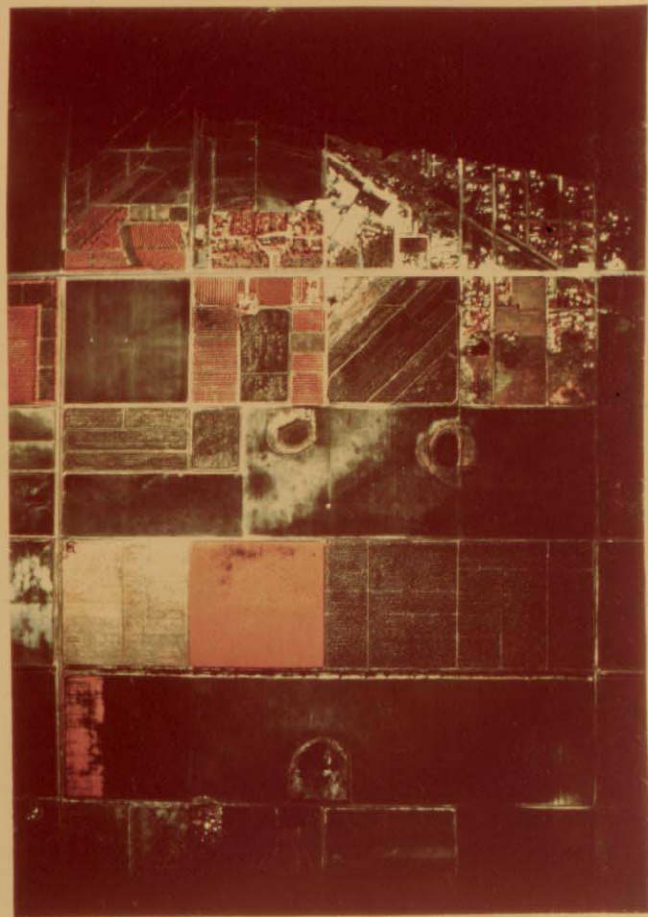
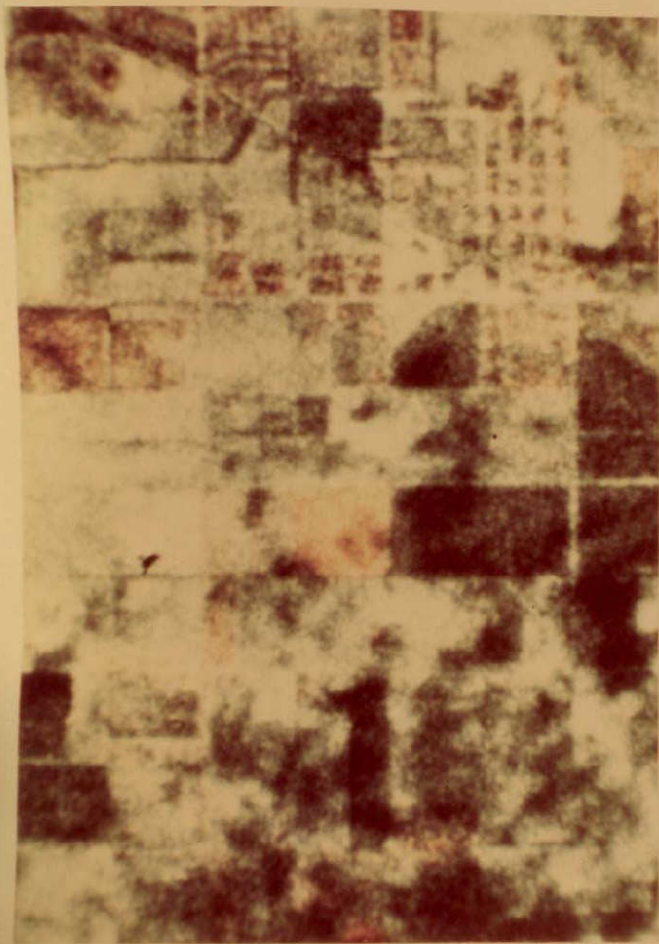


FIGURE 8

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Sciences, 216-30, Mar. 2-4, 1971, Gainesville, Fla.

## FOOTNOTES

- 1/ AA, BB, CC, DD, EE and FF are NASA designations for filters providing the band widths indicated.

## KEY WORDS:

1. Skylab data
2. Agricultural information
3. Density and distribution of host plants of major pest
4. Crop identification
5. Vegetation patterns
6. Avenues of entry of pest species
7. Areas of plant stress
8. Insect infestations
9. Soil patterns
10. Environmental factors